Case Simulink

Solar International – Team 8

Assumptions

Type	Variable	Value	Source
Solar Panel	Irradiance – I_R	$800\ \frac{W}{m^2}$	Estimate from lecutre
	Irradiance at measurement – I_{R0}	$300\ \frac{W}{m^2}$	Estimate given expected I_{SC}
	Short-Circuit Current – I_{SC}	0.27 A	Measurement
	Open-Circuit Voltage – I_{OC}	0.55 V	Measurement
	Saturation Current – I_s	7.3e-10 A	Lecture notes
	Diode Factor – N	1.081 (unitless)	Calculated from measurements
	Thermal Voltage – U_r	0.0257 V	Lecture notes
Motor	Internal Resistance - R_a	3.2 Ohm	Motor data sheet
	Torque Constant –K_t	8.55e-3 Nm/A	Motor data sheet
	Internal Inductance – L_a	0.22e-3 H	Motor data sheet
	Shaft Inertia –I_m	4.1e-7 kg m^2	Motor data sheet
	Motor Damping – C_m	2.2e-5 N m s	Motor data sheet
Vehicle	Mass – m	0.75 kg	Minimum vehicle weight
	Wheel radius – r	0.04 m	Present CAD
	Coefficient of rolling resistance – C_{rr}	0.015 (unitless)	Car Tire on Road
	Gear ratio – n	variable	—
	Losses to transmission – eta	20%	Estimates from lecture
Air Resistance	Frontal Area	0.04 m^2	Estimate from CAD
	Fluid density of air – rho	$1.2\ \frac{kg}{m^3}$	Wikipedia
	Drag coefficient - C_w	0.85 (unitless)	Estimate from table
Environment	Theta	3 degrees	Race parameters
	Distance to slope	6 meters	Race parameters

Basic Principle of Simulation

We designed a simulation using Simulink's Simscape and SimElectronics toolkits. These toolkits allowed us to model both the electrical (e.g. solar panels) and mechanical (e.g. air resistance, motion, other forces) aspects of the system and link them together. Basic assumptions were required to model each part of the physical system and are shown in the table above. Additionally, we created additional forces to model three different behaviors. First, we added a component of gravitational weight which appears perpendicular to the axis of motion when the vehicle is moving up the ramp. Second, we added the force of air resistance in the opposite direction of motion. Third, we added the rolling resistance of the wheels opposite the direction of motion.

Simulink Model

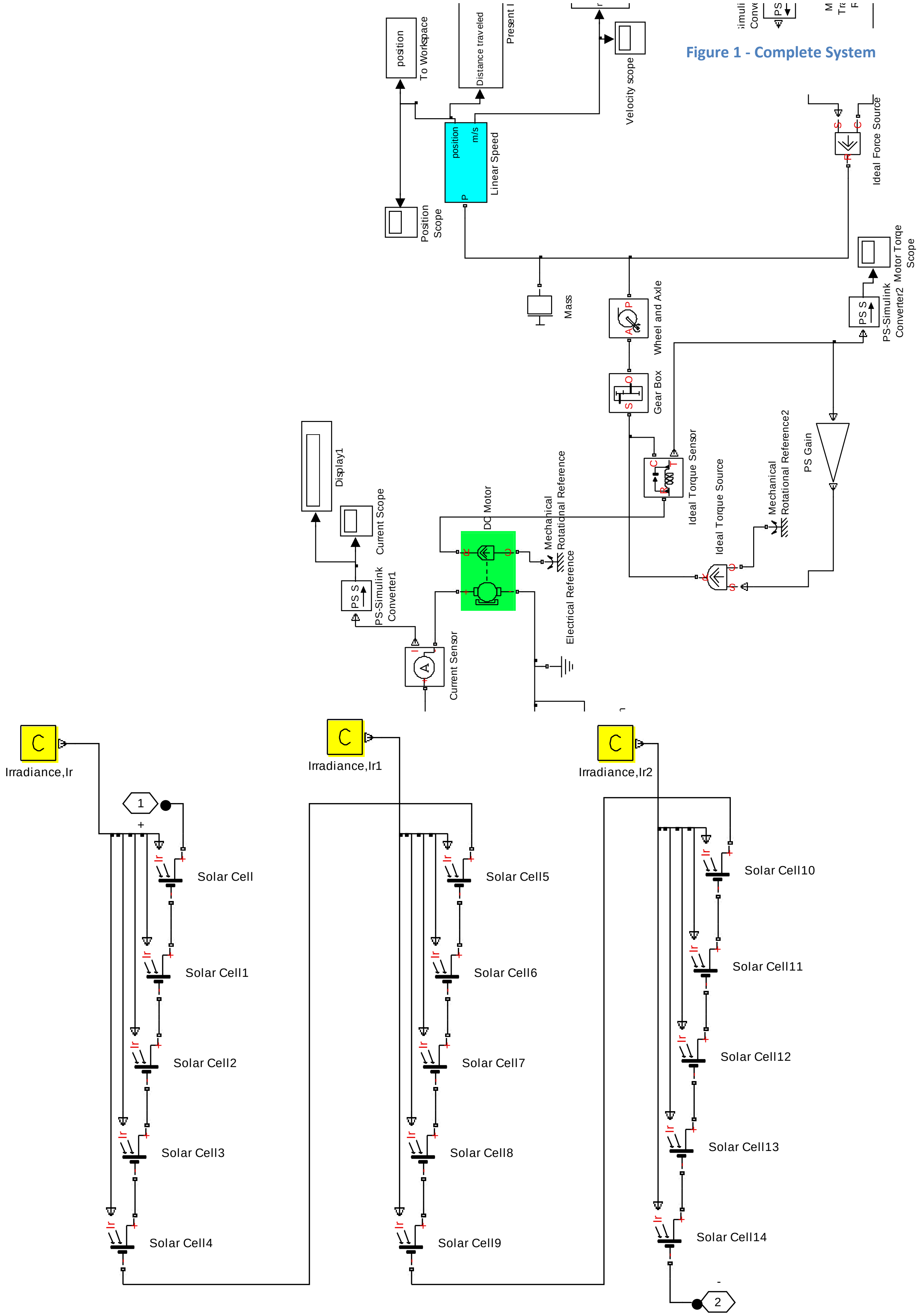

Figure 1 - Complete System

Figure 2 - Solar Cell Array

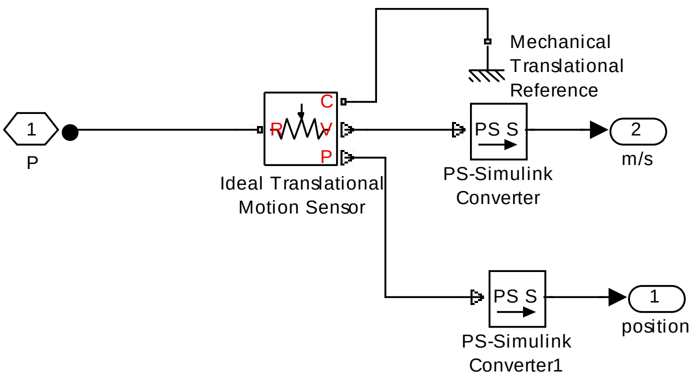

Figure 3 - Conversion to Linear Motion

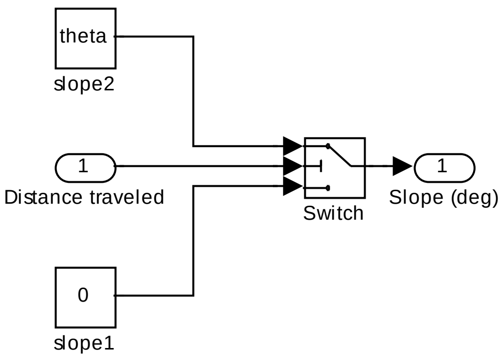

Figure 4 - Slope Switch

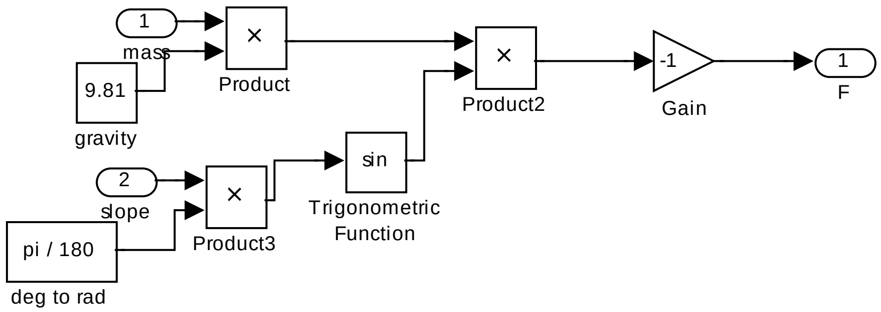

Figure 5 - Gravity Force Calculation

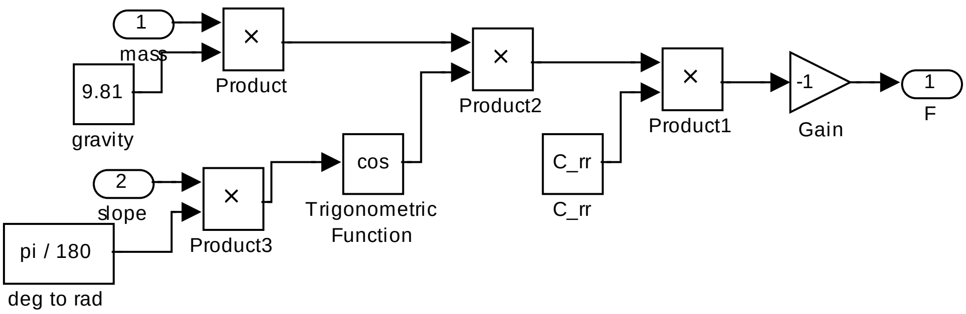

Figure 6-Rolling Resistance Calculation

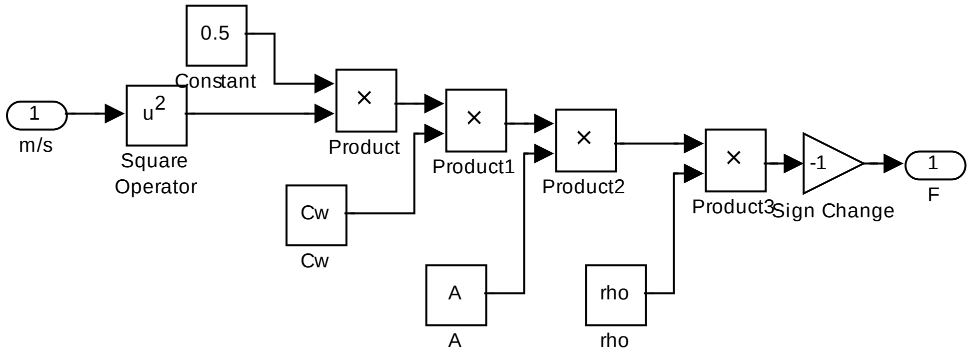

Figure 7 - Air Resistance Calculation

Sample Simulink Results (Gear Ratio = 10)

The following results show the behavior for a number of simulated variables. Discontinuities and other abrupt changes in behavior happen between six and seven seconds when the vehicle abruptly hits the ramp. Linked characteristics (e.g. speed and voltage) have similar behavior. Additionally, the scales of external forces seem appropriate and small.

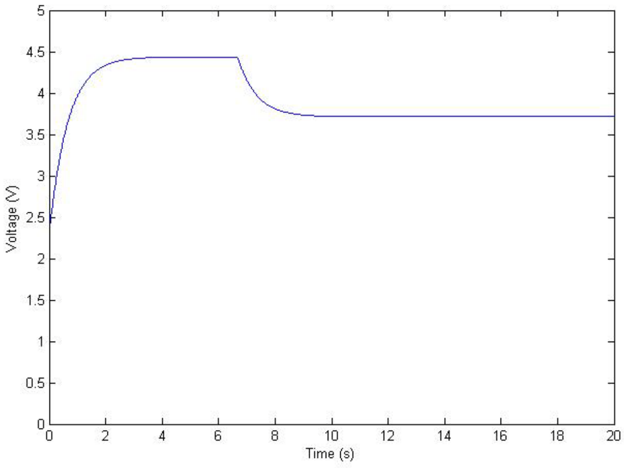

Figure 8 - Simulated Solar Panel Voltage

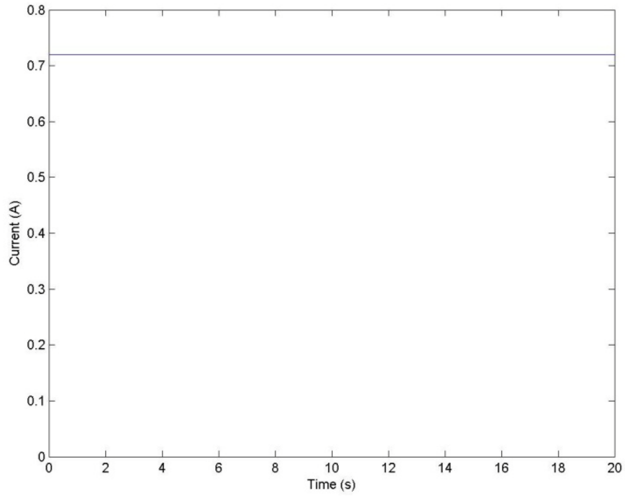

Figure 9 - Simulated Solar Panel Current

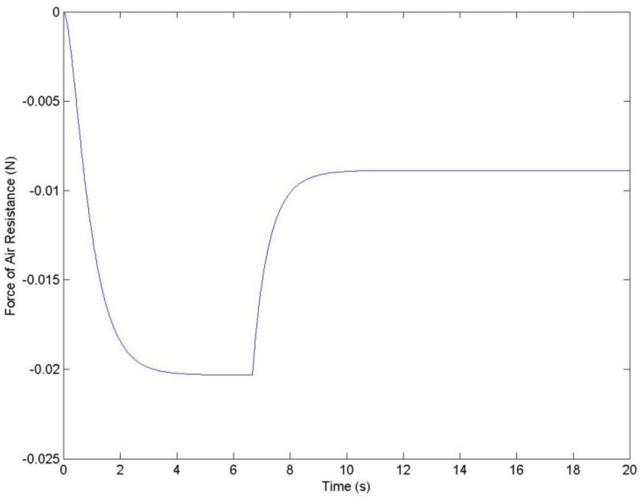

Figure 10 - Simulated Air Resistance

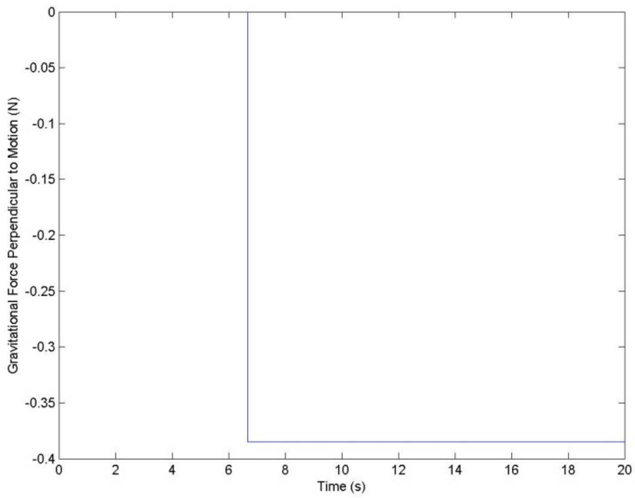

Figure 11 - Simulated Gravitational Force

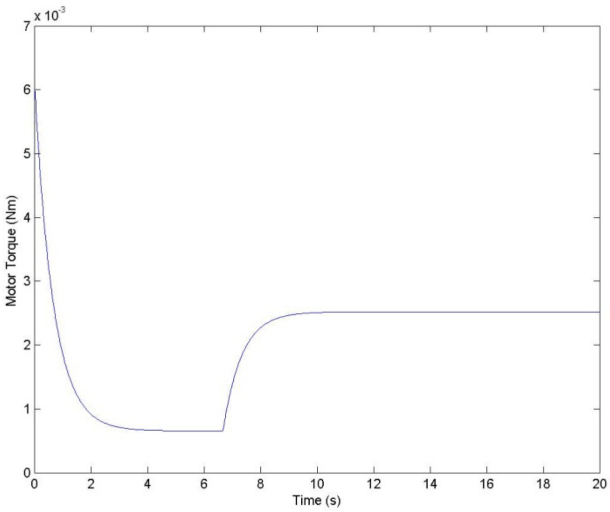

Figure 12 - Simulated Motor Torque

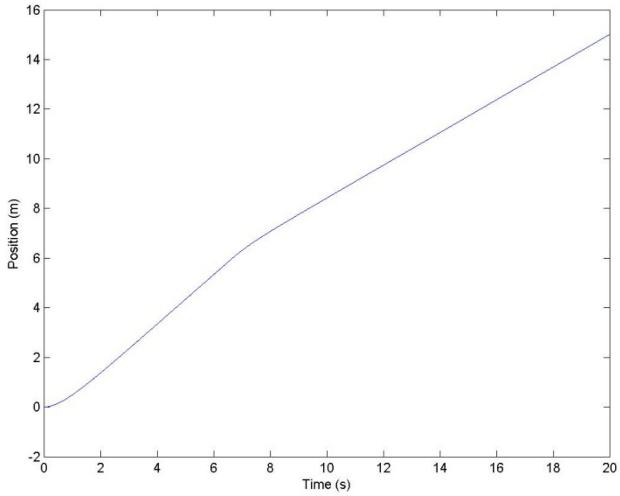

Figure 13 - Simulated Position

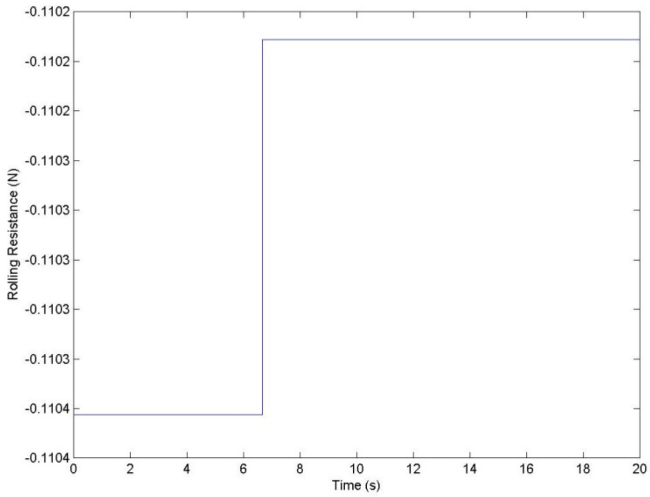

Figure 14 - Simulated Rolling Resistance

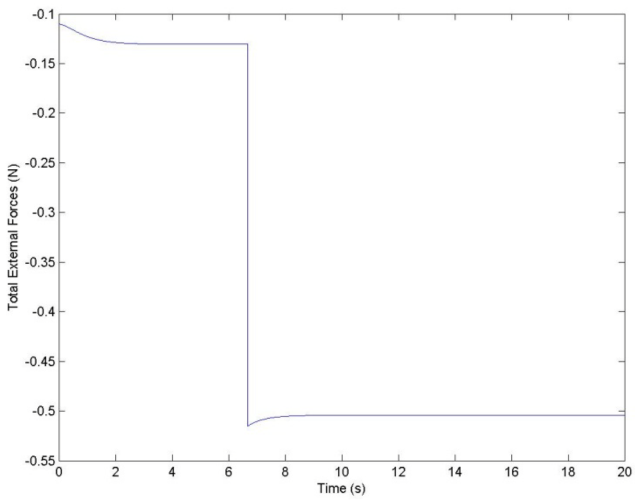

Figure 15 - Simulated Total External Forces (Air Resistance, Gravity, and Rolling Resistance)

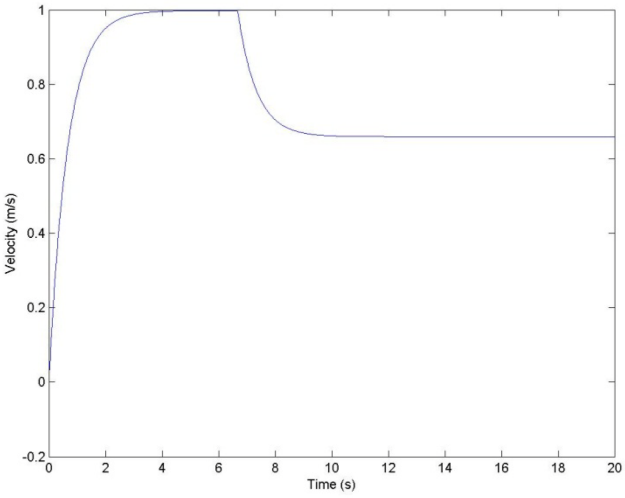

Figure 16 - Simulated Velocity

Optimal Transmission Ratio

We simulated a wide variety of transmissions to identify the transmission which provided the fastest time to the end of the track. We found that a gear ratio of seven provided the optimal result. These results are shown below.

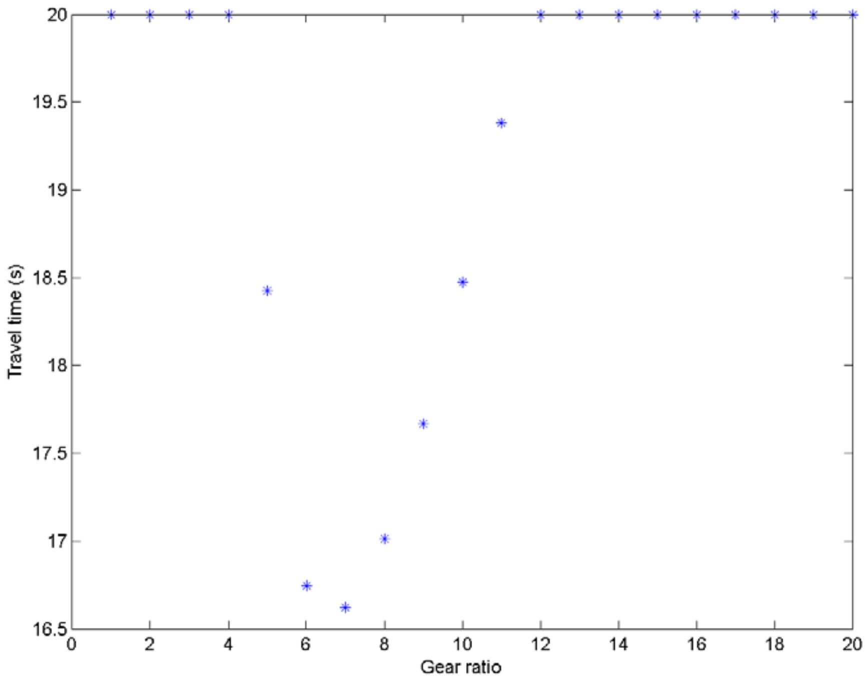

Figure 17 - Vehicle Run Times

Compiled Code

```
% ssv_values.m
% This script provides a single run to the simulink platform
%
% Changelog
% -----------------------------------
% 16MAR11
% Original creation and import of values from ssv_calculation_script
%
% 17MAR11
% Addition of env variables section.
% Added percent loss (eta) to SSV parameters
% Added air resistance parameters
%
% 21MAR11
% Adjusted solar power variables. These need to be reviewed.

%%% Additional environment variables
theta = 3; %degrees
distance_to_slope = 6; %meters
%%% Solar Power
Ir = 800; % W/m^2 - Irradiance
% Ir0 = Ir;
% Isc = 0.88*.8; %Ampere
% Voc = 8.25/15; %Volt
Ir0 = 300;
Isc = .27; %Ampere
Voc = 8.25/15; %Volt
Is= 7.3e-10; %Ampere
N = 1.081;
panel_count = 15; %Number of solar panels
Ur = 0.0257; %Num
%%% Motor parameters
Ra =   3.2; %ohm - internal resistance
Kt=    8.55e-3; %Nm/A - torque constant
La=  0.22e-3; %H - internal inductance
Im =   4.1 / 1000 / 100^2;% kg*m^2 - interta of shaft
Cm_from_datasheet = 433; % rpm / (mN * m)
Cm =  Cm_from_datasheet^-1 / 1000*60 / (2*pi);% N*m/(rad/s) - motor damping
%%% SSV parameter
m = 0.75; % kg
r = .04; % wheel radius [m]
C_rr = 0.015; % coefficient of rolling resistance
n = 10; % gear ratio
eta = -0.2; %percent - losses to transmission - must be negative
%%% Air resistance parameters
A = 0.04; %m^2 - frontal area
rho = 1.2; %kg/m^3 - fluid density of air
Cw = 0.85; %dimensionless - drag coefficient

```

```
% ssv_calculation_script.m
%
% Changelog
% -----------------------------------
% 15MAR11
% Originally copied from Toledo
% Updated a few values in the simulation
%
% 16MAR11
% Removed constants and replaced them in ssv_values.m
%
% 19MAR11
```

```
% Updated simulation ratio

clearall;
ssv_values;

tn=[]; %% initialize empty vector
result=[];

for n=1:20
tn=[tn n];    %% Extend vector with gear ratio n

sim('Step3b',20); % Simulate Simulink model for 20 sec.

[i,j]=find(position>14); % find when position of 14 m is achieved
ifisempty(i)
result =[result 20]; %% if not achieved take time =10 sec
else
result=[result tout(i(1))]; %% put travel time in vector
end
fprintf('Completed simulation with gear ratio %i\n',n);
end

h = figure(1);
plot(tn,result,'*') %% plot gear ratio versus travel time
xlabel('Gear ratio');
ylabel('Travel time (s)');
saveas(h,'results.fig');
saveas(h,'results.png');
[opt,i]=min(result); %%% find minimal travel time

n=tn(i); %% take gear ratio corresponding with minimal travel time
sim('Step3b',20);
```